Massachusetts Institute of Technology
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Cambridge, Massachusetts

LUMINARY Memo #93

TO: Distribution

FROM: J. E. Jones

DATE: 14 July 1969

SUBJECT: Intermediate Throttle-up of LM DPS During CSM-docked Burn

Astronaut procedures for Apollo 9 included a manual throttle-up to 40% thrust a few seconds after ignition during the CSM-docked burn. This intermediate thrust level was added to alleviate a GTS computational underflow which occurred in the CSM-docked configuration at low thrust levels.

In LUMINARY 1A, the GTS was rescaled to eliminate this underflow problem. It is recommended, however, that the intermediate throttle-up procedure be retained during DPS docked burns for future LUMINARY flights when the trimming of the DPS-engine bell at ignition is expected to be accurate. (Such was the case in Apollo 9, SUNDANCE Mission "D".) For small initial mistrims, the presence of the intermediate thrust level significantly reduces the magnitude of the attitude state transients which occur at automatic throttle-up to FTP (Fixed Throttle Position, about 93%), 26 seconds after ignition. These transients are due to two factors associated with the abrupt thrust increase: the roughly proportional thrust-dependent misalignment (compliance) of the engine mount; and, more significantly, the proportional instantaneous increase in the angular acceleration magnitude when the thrust vector is displaced from the c. g. at throttle-up. The simulation results which follow support the above recommendation.

Two simulations were made to determine the effect of the 40% intermediate throttle-up level upon performance during a CSM-docked DPS burn with small initial gimbal mistrims. Run NOTHROTL remained at 10% thrust until automatic throttle-up at 26 seconds. Run 40THROTL ignited to 10% thrust, throttled to 40% thrust 5 seconds after ignition, and automatically throttled to FTP 21 seconds later. The engine bell was initially trimmed such that the thrust vector would point through the c. g. after compliance at

10% thrust in NOTHROTL and 40% in 40THROTL. Both simulations modelled bending, slosh, and compliance, and shared the following programs, environment data files, and initialization:

Program:	LUMINARY Revision 097		
Subprograms:	COMMON. LEM	6/4/69	15:12
	COMMON. UNIVERSE	2/3/69	9:47
Data Files:	UNIV. EPHM 6869	11/24/69	14:23
	LEM 5. NOMINAL	6/4/69	11:21
Fuel Loadings:	DPS - 0.835		
	APS - 1.000		
	SPS - 0.250		
	RCS - 1.000		
Noise Level:	2 Bits		
Engine and RCS Misalignments:	3 - σ Errors		

Figures 1 and 2 show the P, Q, and R attitude errors for runs NOTHROTL and 40THROTL respectively. The large (about -26 degrees) attitude error excursion shortly after throttle-up in NOTHROTL is due primarily to the factor of about 9 instantaneous increase in GTS control authority when throttling from 10% thrust to FTP. (The thrust vector, steering out attitude errors at low thrust, was displaced from the c.g. primarily along the Q-axis at throttle-up.) Throttling from 40% thrust to FTP as in 40THROTL causes an instantaneous acceleration increase of only about a factor of 2. Resulting attitude excursions are small: about 3.5 degrees in R and about -1.5 degrees in Q. These compare very well with transient throttle-up attitude error magnitudes observed during the docked DPS burn of Apollo 9 (see J. E. Jones, Post-Flight Data Analysis Memo #21, June 4, 1969).

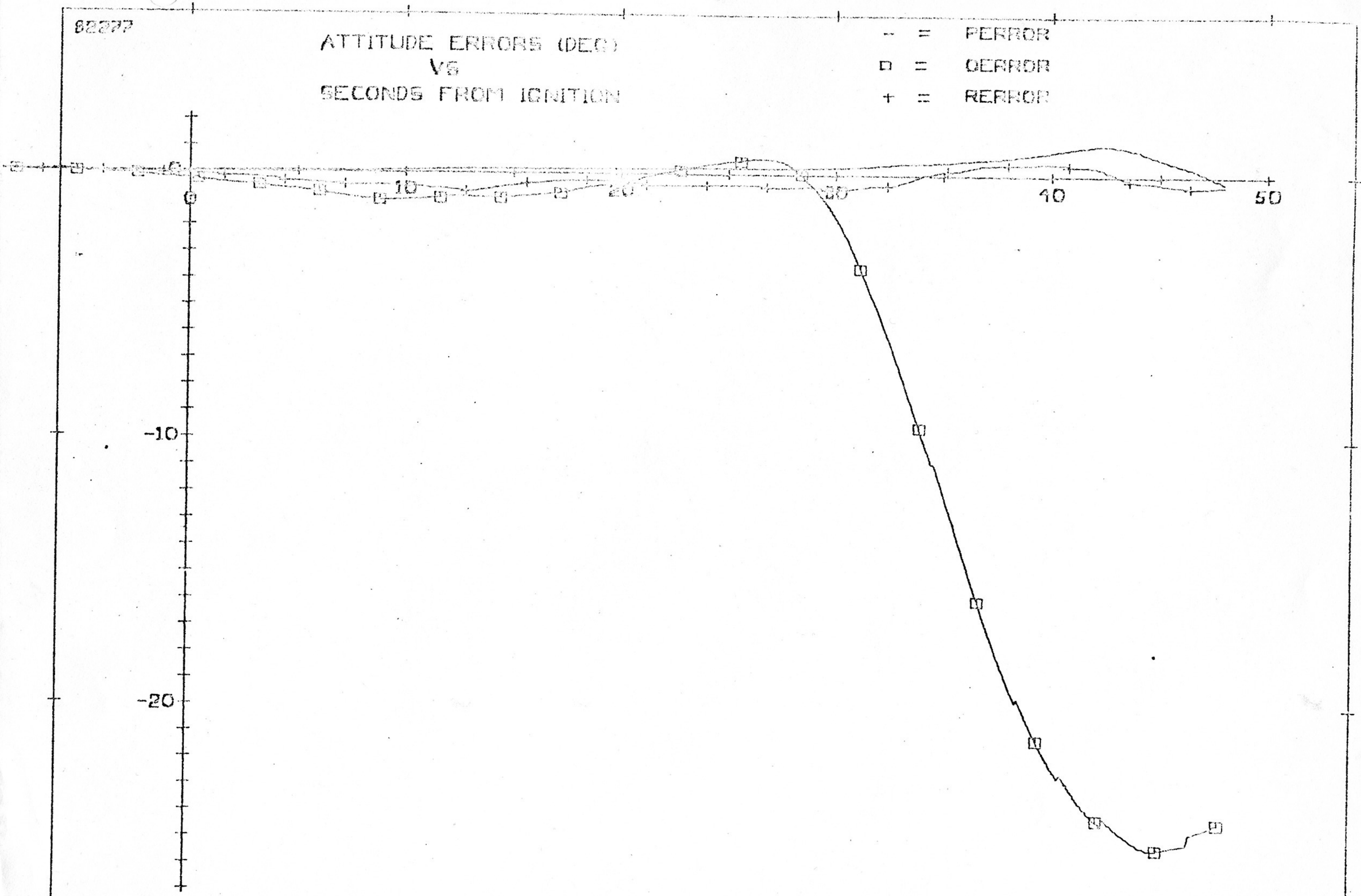

Figure 1: Attitude Error Time History for Run NOTHROTL

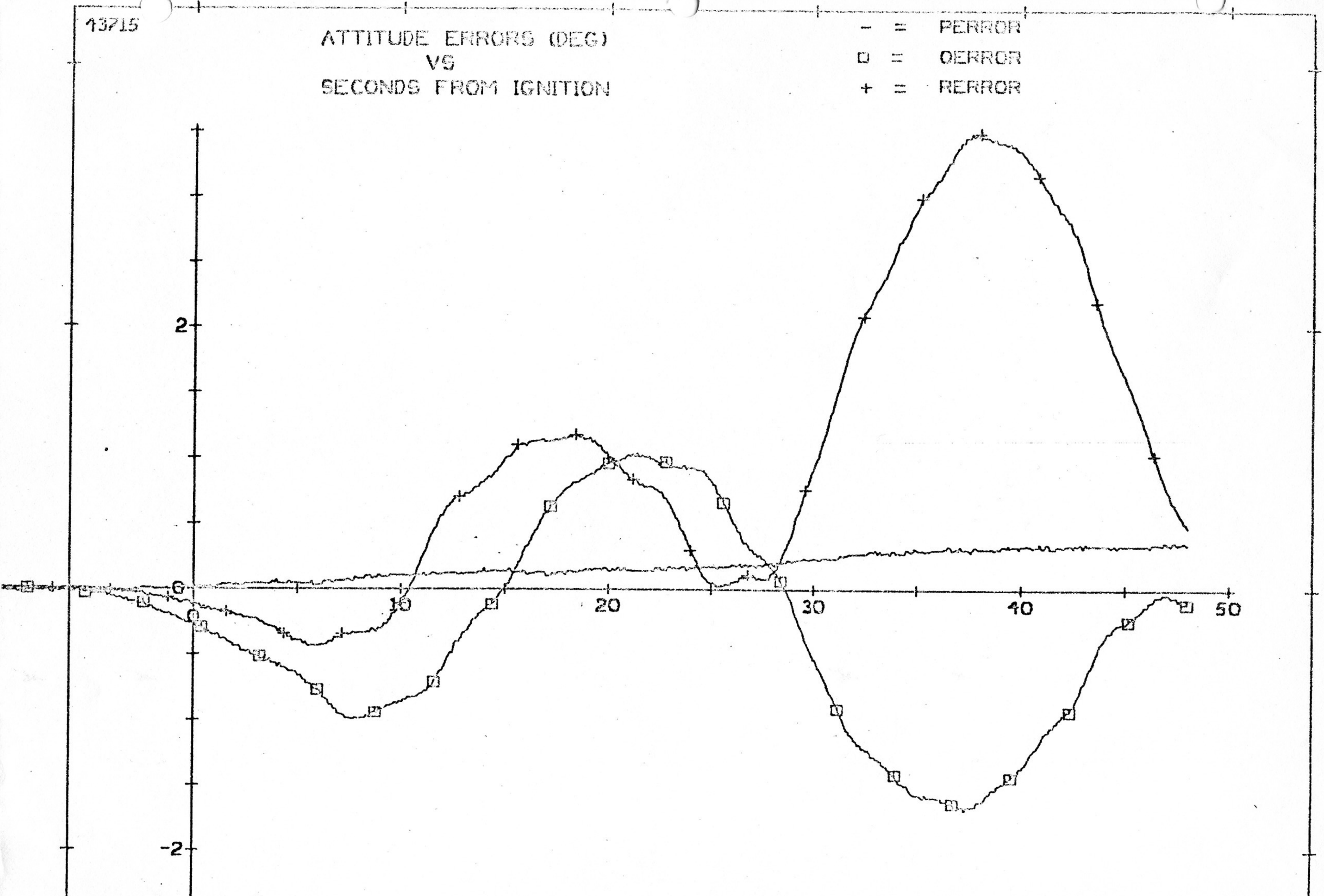

Figure 2: Attitude Error Time History for Run 40THROTL